CHAPTER 5

BACKFILL OPERATIONS

5-1. Placement of backfill.

a. *General*. Backfill construction is the refilling of previously excavated space with properly compacted material. The areas may be quite large, in which case the backfilling operation will be similar to embankment construction. On the other hand, the areas may be quite limited, such as confined areas around or between and beneath concrete or steel structures and areas in trenches excavated for utility lines. Prior to construction of the backfill, the inspection personnel should become thoroughly familiar with the various classes of backfill to be used. They should be able to readily identify the materials on sight, know where the various types of material should be placed, and be familiar with the compaction characteristics of the soil types. Compaction characteristics of various soil types are discussed in appendix B.

b. Good construction practices, and problems. Problems with placement of backfill will vary from one construction project to another. The magnitude of the problems will depend on the type of materials available such as backfill, density requirements, and the configuration of the areas in which compaction is to be accomplished. Problems should be expected during the initial stages of backfill compaction unless the contractor is familiar with compaction characteristics of backfill materials. The inspector can be of great assistance to the contractor during this period by performing frequent water content and density checks. The information from these checks will show the contractor the effects of the compaction procedures being used and point out any changes that should be made.

(1) *Backfilling procedures*. Problems associated with the compaction of backfill can be minimized by following good backfilling procedures. Good backfilling procedures include: processing the material (para. 3-4) before it is placed in the excavation; placing the material in a uniformly spread loose lift of the proper thickness suited to the compaction equipment and the type of material to be used; applying the necessary compaction effort to obtain the required densities; and ensuring that these operations are not performed during adverse weather. Proper bond should be provided between each lift and also between the backfill and the sides of the excavation.

(2) *Compaction equipment, backfill material, and zones.* The type of compaction equipment used to achieve the required densities will usually depend upon the type of backfill material being compacted and the type of zone in which the material is placed.

(*a*) In open zones, coarse-grained soils that exhibit slight plasticity (clayey sands, silty sands, clayey gravels, and silty gravels) should be compacted with either sheepsfoot or rubber-tired rollers; close control of water content is required where silt is present in substantial amounts. For sands and gravelly sands with little or no fines, good compaction results are obtained with tractor compaction. Good compaction can also be achieved in gravels and gravel-sand mixtures with either a crawler tractor or rubber-tired and steelwheeled rollers. The addition of vibration to any of the means of compaction mentioned above will usually improve the compaction of soils in this category. In confined zones, adequate compaction of cohesionless soils in either the air-dried or saturated condition can be achieved by vibratory-plate compactors with a static weight of at least 100 pounds. If the material is compacted in the saturated condition, good compaction can be achieved by internal vibration (for example, by using concrete vibrators). Downward drainage is required to maintain seepage forces in a downward direction if the placed material is saturated to aid in compaction.

(*b*) Inorganic clays, inorganic silts, and very fine sands of low to medium plasticity are fairly easily compacted in open zones with sheepsfoot or rubbertired rollers in the 15,000-pound and above wheel-load class. Some inorganic clays can be adequately compacted in confined zones using rammer or impact compactors with a static weight of at least 100 pounds provided close control of lift thickness and water content is maintained.

(*c*) Fine-grained, highly plastic materials, though not good backfill materials, can best be compacted in open zones with sheepsfoot rollers. Sheepsfoot rollers leave the surface of the backfill in a rough condition, which provides an excellent bond between lifts. In confined areas the best results, which are not considered good, are obtained with rammer or impact compactors.

(3) *Lift thickness*. The loose-lift thickness will depend on the type of backfill material and the compaction equipment to be used.

(*a*) As a general rule, a loose-lift thickness that will result in a 6-inch lift when compacted can be

allowed for most sheepsfoot and pneumatic-tired rollers.
Cohesive soils placed inapproximately 10-inch loose lifts will compact to approximately 6 inches, and cohesionless soils placed in approximately 8-inch base lifts will compact to 6 inches. Adequate compaction can be achieved in cohesionless materials of about 12- to 15inch loose-lift thickness if heavy vibratory equipment is used. The addition of vibration to rolling equipment used for compacting cohesive soils generally has little effect on the lift thickness that can be compacted, although compaction to the desired density can sometimes be obtained by fewer coverages of the equipment.

(b) In confined zones where clean cohesionless backfill material is used, a loose-lift thickness of 4 to 6 inches and a vibratory plate or walk-behind, dual-drum vibratory roller for compaction is recommended. Where cohesive soils are used as backfill in confined zones, use of rammer compactors and a loose-lift thickness of not more than 4 inches should be specified. Experience has shown that "two-by-four" wood rammers, or single air tampers (commonly referred to as "powder puffs" or "pogo sticks') do not produce sufficient compaction.

(4) *Density requirements*. In open areas of backfill where structures will not be constructed, compaction can be less than that required in more critical zones. Compaction to 90 percent of CE 55 maximum dry density as obtained by MIL-STD-621 should be adequate in these areas. If structures are to be constructed on or within the backfill, compaction of cohesionless soils to within 95 to 100 percent of CE 55 maximum dry density and of cohesive soils to at least 95 percent of CE 55 should be required for the full depth of backfill beneath these structures. The specified degree of compaction should be commensurate with the tolerable amount of settlement, and the compaction equipment used should be commensurate with the allowable lateral pressure on the structure. Drainage blankets and filters having special gradation requirements should be compacted to within 95 to 100 percent of CE 55 maximum dry density. Table 5-1 gives a summary of type of compaction equipment, number of coverages, and lift thickness for the specified degree of compaction of various soil types (TM 5-818-1/AFM 88-3, Chap. 7).

(5) *Cold weather*. In areas where freezing temperatures either hamper or halt construction during the winter, certain precautions can and should be taken to prevent damage from frost penetration and subsequent thaw. Some of these precautions are presented below.

(*a)* Placement of permanent backfill should be deferred until favorable weather conditions prevail.
However, if placement is an absolute necessity during freezing temperatures, either dry, cohesionless, non frost-susceptible materials or material containing additives, such as calcium chloride, to lower the freezing temperature of the soil water should be used. Each lift should be checked for frozen material after compaction and before construction of the next lift is begun. If frozen material is found, it should be removed; it should not be disked in place. Additives should not be used indiscriminately since they will ordinarily change compaction and water content requirements. Prior laboratory investigation should be conducted to determine additive requirements and the effect on the compaction characteristics of the backfill material.

(*b*) Under no circumstances should frozen material, from stockpile or borrow pit, be placed in backfill that is to be compacted to a specified density.

(*c*) Prior to halting construction during the winter, the peripheral surface drainage system should be checked and reworked where necessary to provide positive drainage of surface water away from the excavation.

(*d*) Foundations beneath structures and backfill around structures should not be allowed to freeze, because structural damage will invariably develop. Structures should be enclosed as much as possible and heated if necessary. Construction should be scheduled so as to minimize the amount of reinforcing steel protruding from a partially completed structure since steel will conduct freezing temperatures into the foundation.

(*e*) Permanent backfill should be protected from freezing as discussed in paragraphs 2-3h (3) and (4).
Records should be made of all temporary coverings that must be removed before backfilling operations are resumed. A checklist should be maintained to ensure that all temporary coverings are removed at the beginning of the next construction season.

(*f*) During freezing weather, records should be kept of the elevation of all critical structures to which there is the remotest possibility of damage or movement due to frost heave and subsequent thaw. It is important that frost-free bench marks be established to which movement of any structure can be referenced.
Bench marks also should be established on the structures at strategic locations prior to freezing weather.

(*g*) At the beginning of the following construction season and after the temporary insulating coverings are removed, the backfill should be checked for frozen material and ice lenses, and the density of the compacted material should be checked carefully before backfilling operations are resumed. If any backfill has lost its specified density because of freezing, it should be removed.

(6) *Zones having particular gradation requirements*. Zones that have particular gradation requirements include those needed to conduct and control ' seepage, such as drainage blankets, filters, and zones

Table 5-1. Summary of Compaction Criteria[a]

Soil Group	Soil Types	Degree of Compaction	Fill and Backfill — Typical Equipment and Procedures for Compaction: Equipment	No. of Passes or Coverages	Comp. Lift Thick., in.	Placement Water Content	Field Control
Pervious (Free-Draining)	GW GP SW SP	Compacted: 90 to 95% of CE 55 maximum density; 75 to 85% of relative density	Vibratory rollers and compactors	Indefinite	Indefinite	Saturate by flooding	Control tests at intervals to determine degree of compaction or relative density
			Rubber-tired roller[b]	2-5 coverages	12		
			Crawler-type tractor[c]	2-5 coverages	8		
			Power hand tamper[d]	Indefinite	6		
		Semicompacted: 85 to 90% of CE 55 maximum density; 65 to 75% of relative density	Rubber-tired roller[b]	2-5 coverages	14	Saturate by flooding	Control tests as noted above, if needed
			Crawler-type tractor[c]	1-2 coverages	10		
			Power hand tamper[d]	Indefinite	8		
			Controlled routing of construction equipment	Indefinite	8-10		
Semipervious and Impervious	GM GC SM SC ML CL OL OH MH CH OH	Compacted: 90 to 95% of CE 55 maximum density	Rubber-tired roller[b]	2-5 coverages	8	Optimum water content	Control tests at intervals to determine degree of compaction
			Sheepsfoot roller[e]	4-8 passes	6		
			Power hand tamper[d]	Indefinite	4		
		Semicompacted: 85 to 90% of CE 55 maximum density	Rubber-tired roller[b]	2-4 coverages	10	(A) Optimum water content (B) By observation; wet side-maximum water content at which material can satisfactorily operate, dry side-minimum water content required to bond particles and which will not result in voids or honeycombed material	(A) Control tests as noted above, if needed (B) Field control exercised by visual inspection of action of compacting equipment
			Sheepsfoot roller[e]	4-8 passes	8		
			Crawler-type tractor[c]	3 coverages	6		
			Power hand tamper[d]	Indefinite	6		
			Controlled routing of construction equipment	Indefinite	6-8		

Note: The above requirements will be adequate in relation to most construction. In special cases where tolerable settlements are unusually small, it my be necessary to employ additional compaction equivalent to 95 to 100 of compaction effort. A coverage consists of one application of the wheel of a rubber-tired roller or the threads of a crawler-type tractor over each point in the area being compacted. For a sheepafoot roller, one pass consists of one movement of a sheepsfoot roller drum over the area being compacted.

a Prom TM 5-818-1.

b Rubber-tired rollers having a wheel load between 18,000 and 25.000 lb and a tire pressure between 80 and 100 psi.

c Crawler-type tractors weighing not less than 20,000 lb and exerting a foot pressure not less than 6-1/2 psi.

d Power hand tampers weighing more than 100 lb; pneumatic or operated by gasoline engine.

e Sheepsfoot rollers having a foot pressure between 250 and 500 psi and tamping feet 7 to 10 in. in length with a face area between 7 and 16 sq in.

susceptible to frost penetration. Drainage zones are often extremely important to the satisfactory construction and subsequent performance of the structure. To maintain the proper functioning of these zones, care must be taken to ensure that the material placed has the correct gradation and is compacted according to specifications.

c. Special problems. In open zones, compaction of backfill will not generally present any particular problems if proper compaction procedures normally associated with the compaction of soils are exercised and the materials available for use, such as backfill, are not unusually difficult to compact. The majority of the problems associated with backfill will occur in confined zones where only small compaction equipment producing a low compaction effort can be used or where because of the confined nature of the backfill zone even small compaction equipment cannot be operated effectively.

(1) Considerable latitude exists in the various types of small compaction equipment available. Unfortunately, very little reliable information is available on the capabilities of the various pieces of equipment. Depending upon the soil type and working room, it may be necessary to establish lift thickness and compaction effort based essentially on trial and error in the field. For this reason, close control must be maintained particularly during the initial stages of the backfill until adequate compaction procedures are established.

(2) Circular, elliptical and arched walled structures are particularly difficult to adequately compact backfill beneath the under side of haunches because of limited working space. Generally, the smaller the structure the more difficult it is to achieve required densities. Rock, where encountered, must be removed to a depth of at least 6 inches below the bottom of the structure and the overdepth backfilled with suitable material before foundation bedding for the structure is placed. Some alternate bedding and backfill placement methods are discussed below.

(*a*) One method is to bring the backfill to the planned elevation of the spring line using conventional heavy compaction equipment and methods. A template in the shape of the structure to be bedded is then used to reexcavate to conform to the bottom contours of the structure. If the structure is made of corrugated metal, allowance should be made in the grade for penetration of the corrugation crests into the backfill upon application of load. Success of this method of bedding is highly dependent on rigid control of grade during reexcavation using the template. This procedure is probably the most applicable where it is necessary to use a cohesive backfill.

(*b*) Another method of bedding placement is to sluice a clean granular backfill material into the bed after the structure is in place. This method is particularly adapted to areas containing a maze of pipes or conduits. Adequate downward drainage, generally essential to the success of this method, can be provided by sump pumps or, if necessary, by pumping from well points. Sluicing should be accompanied by vibrating to ensure adequate soil density. Concrete vibrators have been used successfully for this purpose. This method should be restricted to areas where conduits or pipes have been placed by trenching or in an excavation that provides confining sides. Also, this method should not be used below the groundwater table in seismic zones, since achieving densities high enough to assure stability in a seismic zone is difficult.

(*c*) Another method is to place clean, granular bedding material with pneumatic concrete equipment under the haunches of pipes, tunnels, and tanks. The material is placed wet and should have an in-place water content of approximately 15 to 18 percent. A nozzle pressure of 40 pounds per square inch is required to obtain proper density. Considerable rebound of material (as much as 25 percent by volume when placed with the hose nozzle pointed vertically downward and 50 percent with the nozzle pointed horizontally) occurs at this pressure. Rebound is the material that bounces off the surface and falls back in a loose state. However, the method is very satisfactory if all rebound material is removed. The material can be effectively removed from the backfill by dragging the surface in the area where material is being placed with a flat-end shovel. Two or three men will be needed for each gunite hose operated.

(*d*) For structures and pipes that can tolerate little or no settlement, lean grouts containing granular material and various cementing agents, such as portland cement or fly ash, can be used. This grout may be placed by either method discussed in (b) and (c) above.
However, grouts may develop hard spots (particularly where the sluice method is used that could cause segregation of the granular material and the cementing agent), which could generate stress concentrations in rigid structures such as concrete pipes. Stress concentrations may be severe enough to cause structural distress. If lean grouts are used as backfill around a rigid structure, the structure must be designed to withstand any additional stress generated by possible hard spots.

5-2. Installation of Instruments. Installation of instrumentation devices should be supervised, if not actually done, by experienced personnel from within the Corps of Engineers or by firms that specialize in instrumentation installation. The resident engineer staff must be familiar with the planned locations of all instruments and necessary apparatus or structures (such as trenches and terminal houses) so that necessary arrangements and a schedule for installation can be made with the contractor and with the office or firm that will install the devices. Inspectors should inspect any instrumentation furnished and installed by the contractor. Records must be made of the exact locations and procedures used for installation and initial observations. Inspectors should ensure that necessary extensions are added for the apparatus (such as lead lines and piezometer tubes) installed within the backfill as the backfill is constructed to higher elevations. Care must be used in placing and compacting backfill around instruments that are installed within or through backfill. Where necessary to prevent damage to instruments, backfill must be placed manually and compacted with small compaction equpment such as rammers or vibratory plates.

5-3. Postconstruction distress. Good backfill construction practices and control will minimize the potential for postconstruction distress. Nevertheless, the possibility of distress occurring is real, and measures must be taken to correct any problems before they become so critical as to cause functional problems with the facility. Therefore, early detection of distress is essential. Some early signs of possible distress include: settlement or swelling of the backfill around the structure; sudden or gradual change of instrumentation data; development of cracks in structural walls; and adverse seepage problems. Detailed construction records are important for defining potential distress areas and assessing the mechanisms causing the distress.